FACILITY COMPOSER:
BUILDING A COMPUTABLE FACILITY MODEL FROM ARMY STANDARD FACILITY DESIGNS AND CRITERIA

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Abstract. As the Army transforms itself into what is now being called the Future Force, installations and facilities will be playing a much larger role in supporting the force. Before Future Force brigades can be deployed, installations must conduct analyses to determine their facility requirements. The difficulty of this task is compounded by the fluid state of information about Future Combat Systems (FCS) and the long lead-time (5 to 7 years for large facilities) built into the Military Construction, Army (MCA) processes. This paper describes new approaches in managing Army Standard facility criteria and requirements, and the use of the Industry Foundation Class (IFC) standard modeling format to capture the computable criteria and requirements during the Army's Planning Charrette Process.

1 Introduction

The Architectural Engineering and Construction (AEC) industry has been making a substantial effort over the past several years to create a standard facility modeling format that better enables their different software applications to work together. This emerging standard, known as the Industry Foundation Class (IFC), is being developed by the International Alliance for Interoperability (IAI) and can be found in recent releases of commercial AEC software. With the evolution of this facility modeling standard, it is now becoming possible to capture criteria and requirements during planning and design, and then to reuse this data during the life cycle of the facility.

The Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) is currently developing a set of facility "architectural" programming tools, called *Facility Composer*, to support the capture and tracking of facility criteria and requirements during planning charrettes. As the facility program, criteria, and requirements are chosen during the charrette process, Facility Composer tools populate the IFC object model. The information in the object model can then be used for downstream analyses such as cost, sustainability, and force protection.

These tools, used by Army Centers of Standardization, Installation Planners, and Corps of Engineers Districts, will ensure that standard criteria and requirements are the basis of all Army facility designs. In addition, they will allow criteria updates to be generated more rapidly, provide consistent project documentation improving credibility with Congress, capture facility requirements for Future Combat Systems, and promote virtual teaming through constant data exchange. The tools will be used during charrettes to capture planning and design decisions for the reliable incorporation of lessons-learned, to rapidly generate a programmatic cost estimate using an IFC import into the Parametric Construction Cost Estimating System (PACES), and to produce programming reports for required project documentation (i.e., facility cost, allowable area, and requirement's justification).

This paper describes research and development in the area of modeling Army standard facility requirements and criteria. It focuses on the Facility Composer set of tools and describes current validation tests and pilot studies of the tools.

2 Army Facilities Standardization and Repetitive Designs

The Department of the Army (DA) has a formal process—to be used as the DA Standard for construction—for developing requirements and designs for facilities. The objective of the Facilities Standardization Program is to "achieve savings and benefits in planning, programming, design, and construction and maintenance of Army facilities" (AR 415-15). Most importantly, the Program should increase credibility with Congress though consistency in project documentation and program development, demonstrate equal treatment among installations by providing consistent designs, and reduce cost and time in design, construction, and maintenance.

The Standards are developed and maintained by Centers of Standardization (COS) at U.S. Army Corps of Engineer Districts. By assigning one team the responsibility of a certain facility type, repeated lessons learned about this facility type can—at a minimum—improve design quality and site planning, simplify project management, reduce change orders, and increase customer satisfaction by providing a facility that meets the user's needs.

The use of the DA Standard is required (when one exists). Some facilities however, are not adaptable to a full standard. Therefore, the COS may use one of three methods (outlined in AR415-15) of standardizing facility requirements: the full standard, definitive design, and the design guide. A full standard consists of drawing and specifications that have enough detail, once site-specific modifications are made, to serve as construction documents. The definitive design includes information on space allocation, functional layout, and configuration recommendations, and also provides guidance for developing the design and construction documents. Finally, the design guide demonstrates example designs by using a combination of graphical and textual information, but does not go to the level of detail of full standards.

3 Planning Charrettes

To get a Military Construction (MILCON) project funded through Congress, installation planners must develop a programming and project development document, known as the DD 1391 Form. For certain facility types and projects, these installation planners may reach out to U.S. Army Corps of Engineers Districts or private Architectural and Engineering (A/E) firms for help in developing the DD 1391 Form.

To maintain credibility with Congress, it is essential that the DD 1391 documents be consistent and reliable. To ensure this, the Department of Army Assistant Chief of Staff for Installation Management (ACSIM) distributed a Memorandum on 03 March 2003 requiring that, beginning in fiscal year 2007; all military construction projects use the planning charrette process to produce a complete DD Form 1391.

The U.S. Army Corps of Engineers Engineering and Construction Bulletin on DD 1391 Planning Charrettes states that "the Planning Charrette should emphasize master planning and identify and resolve issues of standardization, functionality, location, scope, and cost which might otherwise affect execution of the project." For this reason, the Planning Charrette Team for any given standard facility project should include a member of that facility type's COS. During the course of developing and maintaining a standard for a facility, the COS captures and applies information on that facility type in many forms: design quality lessons-learned, planning and design requirements, cost, customer and user feedback, and facilities criteria.

It is the culmination of all this information on a certain facility type, the benefits of having this information at hand during a Planning Charrette, and the emergence of the IFC facility modeling standard that led to the research behind the Facility Composer Process. Two previous efforts in criteria and requirements management also influenced the development of Facility Composer, the Software Environment for Early Phases of Building Design (SEED), and the Modular Design System (MDS). The School of

Architecture at Carnegie Mellon University developed SEED (Flemming et al. 1995). The Army Reserve and National Guard funded MDS to ensure that they would receive consistent designs (which paper-based design guidance was not producing). They wanted an automated concept design tool that would capture their facility requirements and restrict, in some ways, their design firms from diverging from their guidance.

4 Facility Composer Process

The most important concept of Facility Composer is that Army and/or other agency-specific computable criteria and requirements are associated with a growing facility model that continues throughout the life cycle of the facility. While many volumes of government design criteria exist in the form of design guides, regulations, technical manuals, and web pages, few, if any, of these are expressed in a computable format. In addition, current design systems do not provide a way to directly interact with these criteria, nor do they provide an efficient way to extend the functionality of an application to directly support criteria usage. The evolution of IFC facility modeling standards will help to overcome these restrictions.

Following the concept of Views (currently one-on-one vendor view), as demonstrated by the Building Lifecycle Interoperable Software (BLIS), the Facility Composer process populates the IFC model at certain stages in the early planning and programming process. After an initial library template is developed for a facility type in Requirements Composer, a planner uses Planning Composer to turn the facility template into project specific information during a planning charrette. When satisfied that all requirements are met for the project, Planning Composer will export an Industry Foundation Class Exchange Mark-up Language (IFC-XML) file for use in downstream analysis, such as Layout Composer, Parametric Cost Estimate, and DD 1391 Form project documentation. Figure 1 outlines the current interoperability process for Facility Composer and other Commercial Off the Shelf (COTS) and Government Off the Shelf (GOTS) related applications.

Another important aspect of the process to note is the timing of the IFC-XML file exchange between Planning Composer, Layout Composer, and the Life Cycle Model. The Corps of Engineers, as Project Manager on Military Construction projects, contracts the majority of the design work to private Architectural and Engineering (A-E) firms. The points at which Facility Composer exchanges an IFC file are also good break points for working within the MILCON contracting process. Also, the IFC modeling standard should eventually eliminate the need to specify vendor specific formats or products in contract deliverables. For example, it should no longer be necessary to require construction document deliverables in Autodesk's

*.dwg or Bentley's *.dgn file format. The A-E contract scope would specify IFC compliance only, and the A-E would be free to work in their product of choice.

ERDC-CERL predicts that the XML format will be the future way to document IFCs. The Facility Composer Process was consequently designed to use IFC-XML as the format for exchanging IFCs between applications. Major vendors currently work with the Part 21 file format; however there is an initiative to take an IFC-XML file to a Part 21 file, and IAI has developed translator methods for going from Part 21 to XML.

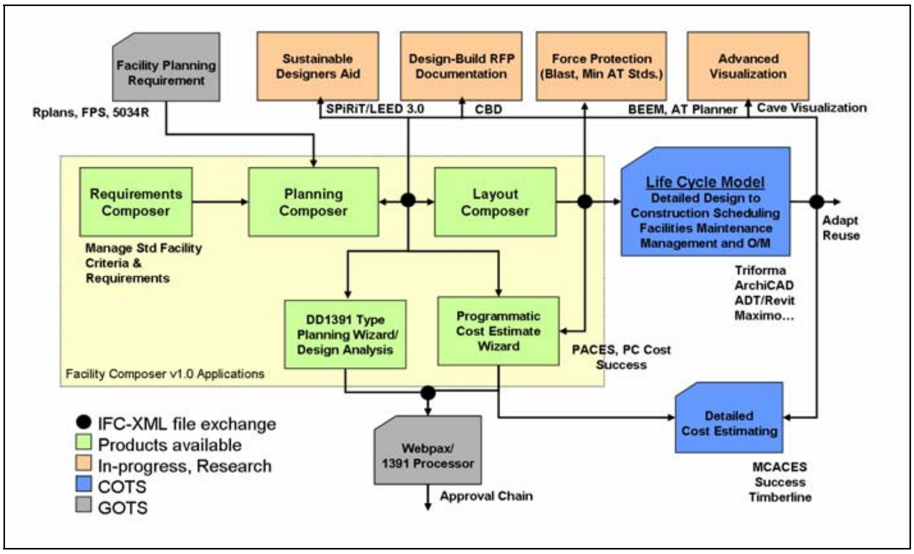

Figure 1: Facility Composer Interoperability Process

5 Object Model Gaps

During the development of Facility Composer, it became apparent that the existing IFC model did not have the early design objects needed to capture certain elements of early architectural programming. An Early Design project was proposed and accepted, by ERDC-CERL and other interested members, in the Fall of 2002. The purpose was to investigate and provide IFC-based modeling of data to support the early design and programming processes.

5.1 IAI EARLY DESIGN PROJECT

The intent of the project was to make early design information available, in an interoperable product data model form, so that the information can be used throughout the design lifecycle. It emphasized performance based requirement specification as a priority for early design information modeling. Specifically, the project aimed to identify and define the information objects that are used by owners; to encourage users to define what is required during the early design phase; and to develop IFC support for refining the building concept, spatial functions, spatial programming; design criteria specification and early geometric representations (e.g., blocking and stacking, bubble diagramming).

The IAI Early Design Project Team conducted research to identify the overall early design process. The proposed process as designed by the team breaks down as.

- Program Planning
- Activity Data Collection
- Site Evaluation
- Data and Alternatives Analysis
- Review and Revision
- Building Diagrammatics
- Parametric Cost Estimate.

At this point, each area had limited or no capability in the existing Industry Foundation Class object model. Work was needed to expand the model to support the early programming, planning, and design phases. Most gaps were found in the Program Planning, Activity Data Collection, and Data and Alternatives Analysis. The following sections define the processes used to determine the gaps in the IFC model.

5.1.1 *Program Planning*

This process will develop a schedule of tasks to complete the programming process. The overall project schedule and reference material such as template schedule, checklists, and sample projects are controls in this process. This type of information will usually be gathered through the Portfolio and Asset Management: Performance Requirements (PAMPeR) process. (The PAMPeR project is an on-going IAI project developed in conjunction with the Early Design Project.) This process requires interplay between stakeholders, design professionals, and software.

5.1.2 *Activity Data Collection*

Activity Data Collection is the process in which information needed to produce the program is captured. The purpose of this phase is for the design professional to collect and identify routine information. The information includes (but is not limited to) functional/activity requirements, dimensional requirements, and specific criteria and/or requirements.

5.1.3 *Data and Alternatives Analysis*

At this stage, the design professional will begin to gather all information collected either through the PAMPeR or Early Design processes and to organize it is such a way that will allow them to start to develop the program. The design professional will use various methods to test and uncover the concepts used to determine the needs of the project. An example of a critical part of this process is the process of creating relationship diagrams, accumulate alternatives, and perform analysis on those alternatives to compare and select one or more alternatives to present to the client.

6 Facility Composer Tools

Facility composer consists of three main tools, Requirements Composer, Planning Composer, and Layout Composer. These main tools are extended by Wizards that aid in discipline-specific planning and analysis tasks.

6.1 REQUIREMENTS COMPOSER

Facility Composer relies on a facility-specific library of functions, criteria, and requirements from which the architectural program is developed. This library is essentially a template for beginning a new facility project. The template contains information similar to what could be found in a definitive design or design guide standard. Each facility type owner, whether a COS or other agency, will be able to create and customize these libraries using the web-enabled Requirements Composer application (Figure 2). Those authorized to use this tool can add new architectural functions and update criteria. Requirements Composer will then export the criteria library in an XML-based format for use by Planning Composer.

Requirements Composer also enables the development of component libraries. Component libraries also contain criteria and requirements, but the information contained in a component library is attached to a main facility template library. The reason for this is to make updates to the libraries easier. For example, an Army Reserve Training Center main library will contain functional requirements, like the need for an Arms Vault, Assembly Hall, Maintenance Bay, as well as building, function, and story requirements like exterior wall construction. The COS for the Training Center will update this library on a regular basis. A component library contains criteria that are not facility type specific. The library contains information relevant to many facility types, such as force protection, mechanical analysis, code compliance, etc. This type of criteria is maintained by others in industry or government such as the U.S. Army Corps of Engineers Omaha District’s Force Protection Center and International Building Code distributors.

Component libraries also help in working with Commercial Off-the-Shelf (COTS) applications. To interact with COTS tools, it is not necessary to modify the main facility template, but to add the requirements needed to interoperate with the COTS through a component library. Currently, Facility Composer uses a component to add the data/requirements needed to generate a programmatic cost estimate in the Parametric Construction Cost Estimating System (PACES).

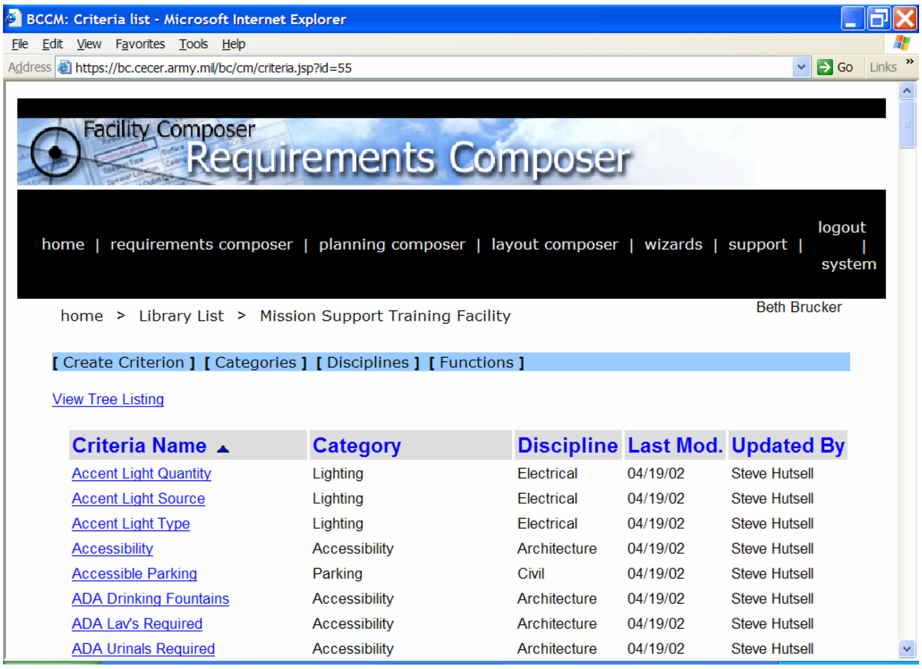

Figure 2: Requirements Composer, Mission Support Training Facility Library, Criteria and Requirement's Listing

6.2 PLANNING COMPOSER

Planning Composer (Figure 3) is used to develop a facility "architectural" program and to add and set project-specific criteria. It assists in developing traditional information such as the total project area and allocation of area to specific architectural functions such as circulation and offices. The Planning Composer interface is generated according to the XML library downloaded from Requirements Composer. It contains discipline-specific criteria (Figure 4) such as requirements for structural, electrical, HVAC, lighting, and plumbing. The level of detail in the architectural program varies from project to project, and can be specified as such in the system. In addition to facilitating the development of the architectural program, Planning

Composer can also be used as a checklist for participants to go through to ensure that all facility criteria and requirements are met.

With just a few parameters set, the information in Planning Composer is sufficient to prepare a parametric cost estimate using a minimally populated IFC model. For example, it is acceptable to create a project that contains a list of architectural functions and their allocated areas without deciding how many buildings will be required. On the other hand, the planner may create a project with detailed information such as the number of buildings and the number of stories in each building. (Obviously, the latter cost estimate will be more accurate.)

Once the architectural program has been completed, Planning Composer will support a programming level cost estimate with preliminary cost estimating tools such as the Parametric Construction Cost Estimating System (PACES™) via an XML-based file exchange. In addition, other applications that comply with the IAI or BLIS standard can also be used.

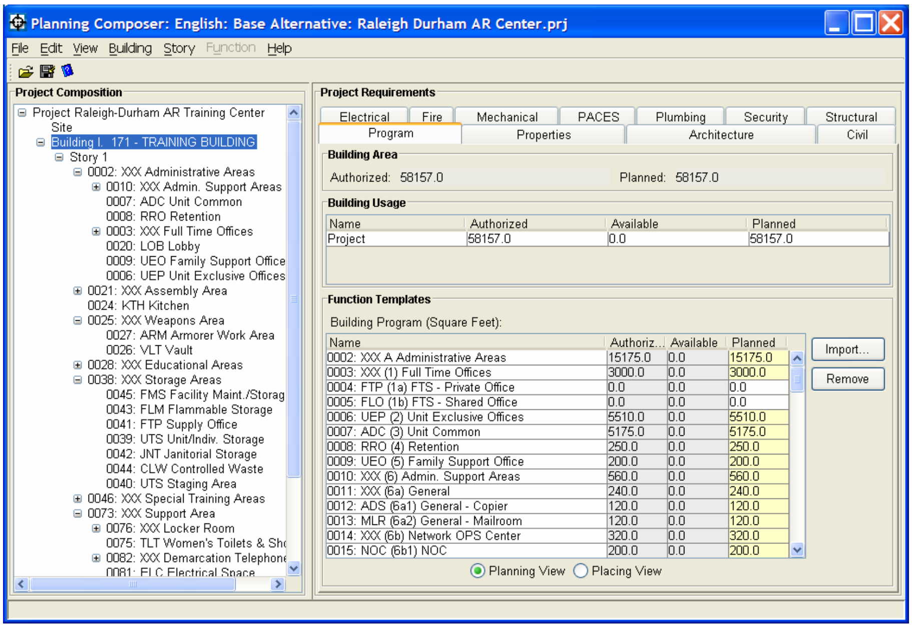

Figure 3: Planning Composer, Architectural Programming Tab and Project Hierarchy

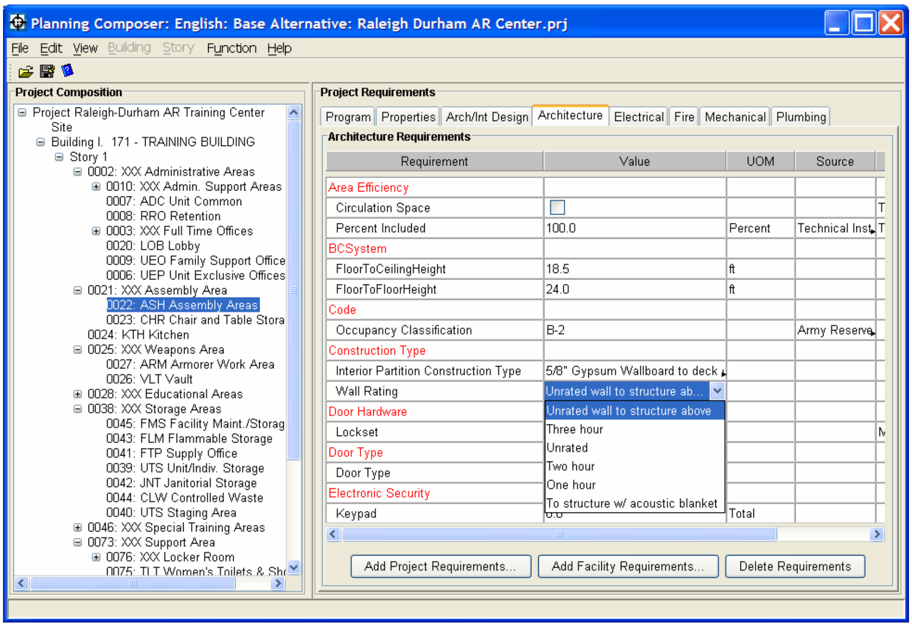

Figure 4: Planning Composer, Architectural Criteria and Requirements for an Assembly Hall

6.3 LAYOUT COMPOSER

Layout Composer (Figure 5) supports the creation of programmatic facility designs. Layout Composer currently works in conjunction with Bentley's MicroStation platform Version 8 and uses the programmed area and criteria established in Planning Composer as a point of reference and comparison during design. In this phase, the architect would determine how many stories are needed and what functions would work on which stories (i.e., blocking and stacking). The planner can also explore conceptual alternatives to determine the best overall solution based on desired adjacencies and functionality.

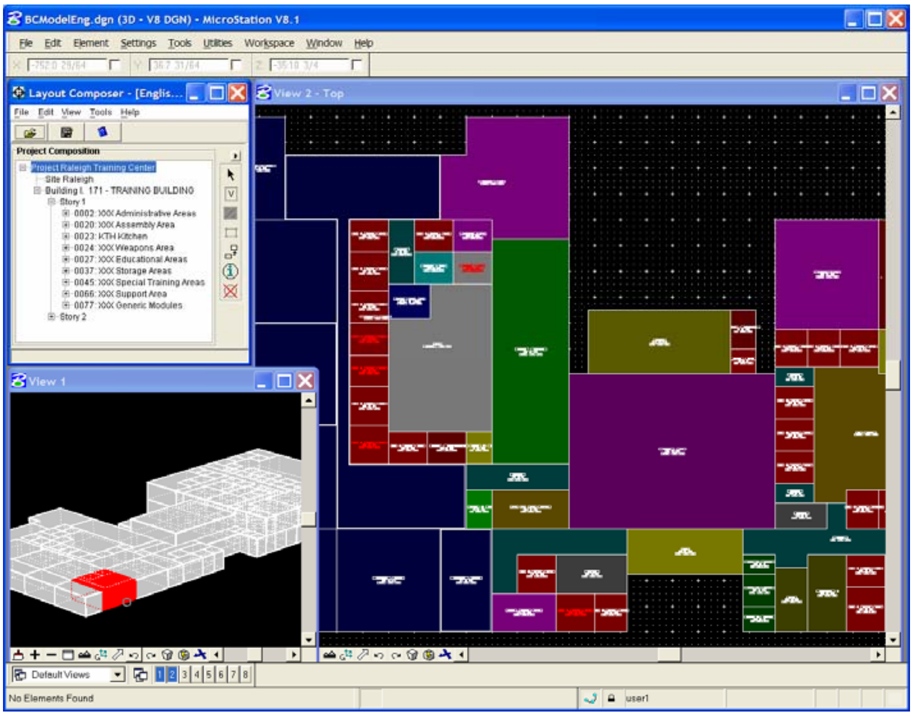

Figure 5: Layout Composer, Army Reserve Training Center Proposed for Raleigh-Durham, North Carolina

6.4 WIZARDS

Wizards are software components that operate on a discrete design task by taking criteria and user input to create or manipulate a building and criteria model rapidly, according to recognized practices.

A Wizard knows how to use the criteria data expressed in the Facility Composer system to create or analyze something in a useful way. An example of a simple wizard might be one that determines the number of faucets required for a restroom within a certain building type with a particular building occupancy level, based on standard design criteria tables. This assists the designer in ensuring that the design solution meets the design guide requirements, and ensures that the customer's requirements are being satisfied.

The different categories of Wizards envisioned include, but are not limited to: Criteria Wizards, Model Generation Wizards, and Analysis Wizards. Analysis Wizards mostly interact with third-party analysis applications. Examples of these might include: energy analysis, security analysis, and force protection analysis. Model Generation Wizards interact with commercial CAD software to generate model components and objects through parametric modeling formulas or manual specification. An example of this could be a Duct Layout Wizard. Criteria Wizards assist a planner by providing a process, which consist of questions, data options, and structured data entry, and from which an algorithm or calculation is performed to arrive at a value for a particular criteria.

The Parking Wizard example that follows would be considered a Criteria Wizard. Table 1, taken from the Army's Technical Instruction 800-1 document, lists the calculations and/or algorithms needed to determine the number of parking stalls authorized, by facility type.

TABLE 3-5 AUTHORIZED PARKING STALL QUANTITIES BY FACILITY TYPE FOR NON-ORGANIZATIONAL - PRIVATELY OWNED VEHICLES (POV)

FACILITY TYPE	NUMBER OF PARKING STALLS
Administration, Headquarters and Office Buildings.	60% of assigned personnel.
Bakeries.	38% of civilian employees; largest shift.
Bank and Credit Union (When not included in a Community Shopping Center).	2% of authorized customers served.
Cafeteria, Civilian (When not included in a Community Shopping Center).	15% of seating capacity.
Central Food Preparation Facilities.	38% of military and civilian food service operating personnel; largest shift.
Chapels.	30% of seating capacity.
Child Development Centers.	1 stall per every 4 children and 100% of staff.

Table 1: Authorized Parking Criteria by Facility Type from Technical Instruction 800-1, Table 3-5

The steps below demonstrate the process a planner would take to populate parking criteria in Planning Composer during a Child Care Center's planning charrette. First the planner would enter the occupancy of children and staff for the facility (Figure 6), hit compute, and find the number of parking stalls (45) authorized and required for that facility type.

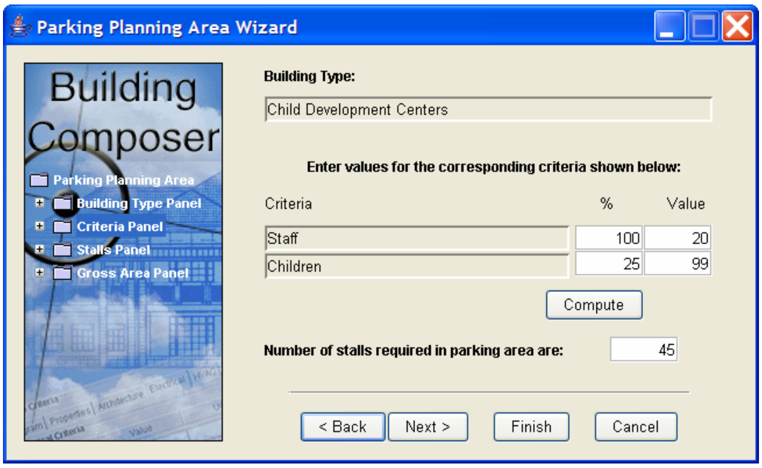

Figure 6: Parking Wizard, Computing Number of Stalls

Next, according to accessibility codes, the wizard will automatically compute the number of accessible parking stalls required per number of stalls (Figure 7).

Figure 7: Parking Wizard, Step 2, Computing Number of Assessable Stalls

The planner can then adjust, if needed, the engineering rule of thumb on area per stall (Figure 8). The wizard then computes the parking area needed for this project and would populate the parking requirements (Figure 9) on the civil tab in Planning Composer for the Child Development Center project.

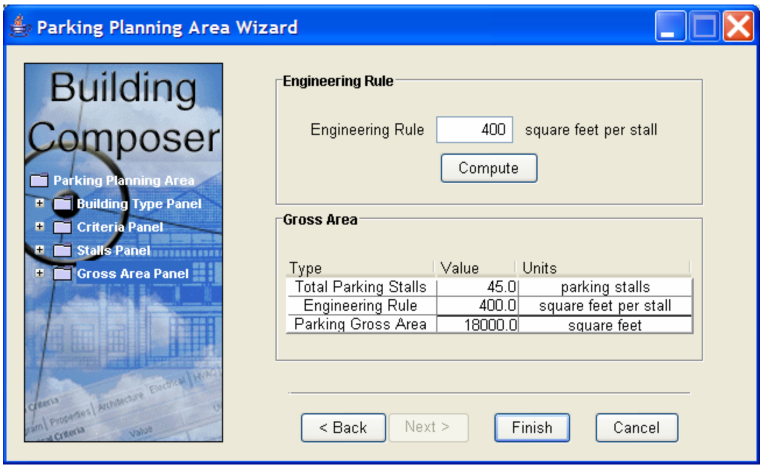

Figure 8: Parking Wizard, Computing Gross Area of Parking by Editing the Parking Stall Engineering Rule Variable

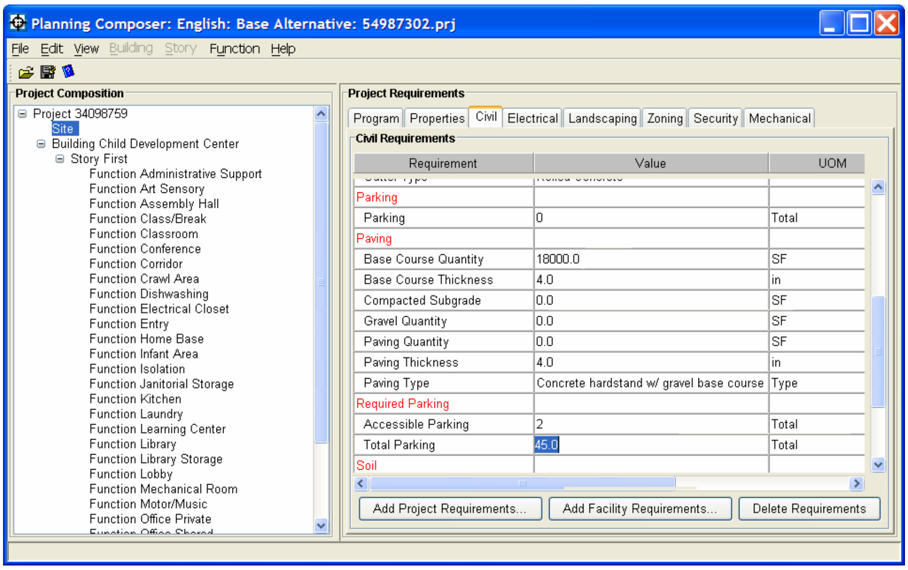

Figure 9: Planning Composer, Parking Criteria Populated by Wizard on Civil Tab of Child Development Center Project

7 Status of Facility Composer Tools

7.1 ARMY RESERVE PILOT STUDY

The Center of Standardization (COS) for the Army Reserve is located at the U.S. Army Corps of Engineer Louisville District. Execution of all new military construction for Army Reserve facilities goes through and is centrally managed by the Louisville District. Currently the Army Reserve and its A/E contractors are using MDS. They are currently funding a pilot study of Facility Composer on an Army Reserve Training Center and Operations Maintenance Shop, scheduled for fiscal year 2007 and in Raleigh-Durham, NC. A large part of this effort is to move the Training Center and Operations Maintenance Shop cost models, previously developed in a detailed cost estimating system, to a parametric cost estimating methodology in PACES.

The Phase I validation strategy of this pilot study is to compare programmatic costs from the old cost system with the imported IFC-XML results in PACES. Phase II is to successfully exchange the facility program, criteria, and requirements to Bentley's Triforma modeling software via an IFC-XML or Part 21 file.

7.2 DEPARTMENT OF STATE PILOT STUDY

The Department of State is currently funding a pilot study of their Marine Security Guard Housing (MSGQ). An analysis of the effectiveness of the Facility Composer tools with respect to the U.S. Department of State Oversees Buildings Operation's (OBO) Planning/Design/Construction process will be conducted and a set of recommendations made regarding opportunities for software integration and process improvement.

This pilot study will specifically look at exchanging the facility model with other A/E software applications. The Department of State currently uses US Cost's Success Estimator cost estimating system and AutoDesk's Architectural Desktop modeling software.

7.3 ARMY – FULL FACILITY STANDARD PILOT STUDY

The Army's Chapel design is a full standard, consisting of a 200, 400, and 600 seat chapel. Figure 10 shows the proposed process for conducting a pilot test on a full standard design for the active Army. Currently, the U.S. Army Corps of Engineer Omaha District is the COS for the Chapel.

The process below (Figure 10) demonstrates how the distribution and use of Army facility standard designs, in an IFC modeling format, works within the current system. As the COS for a certain facility type gains design quality lessons learned on criteria and requirements during design reviews, they can quickly update the facility template and distribute through the DA Standards Portal for use in planning charrettes. This way, installation planners, A/Es, and Corps Districts have the latest facility standard information and can use the template during a planning charrette to quickly generate an accurate programmatic cost estimate and DD1391 type project documentation.

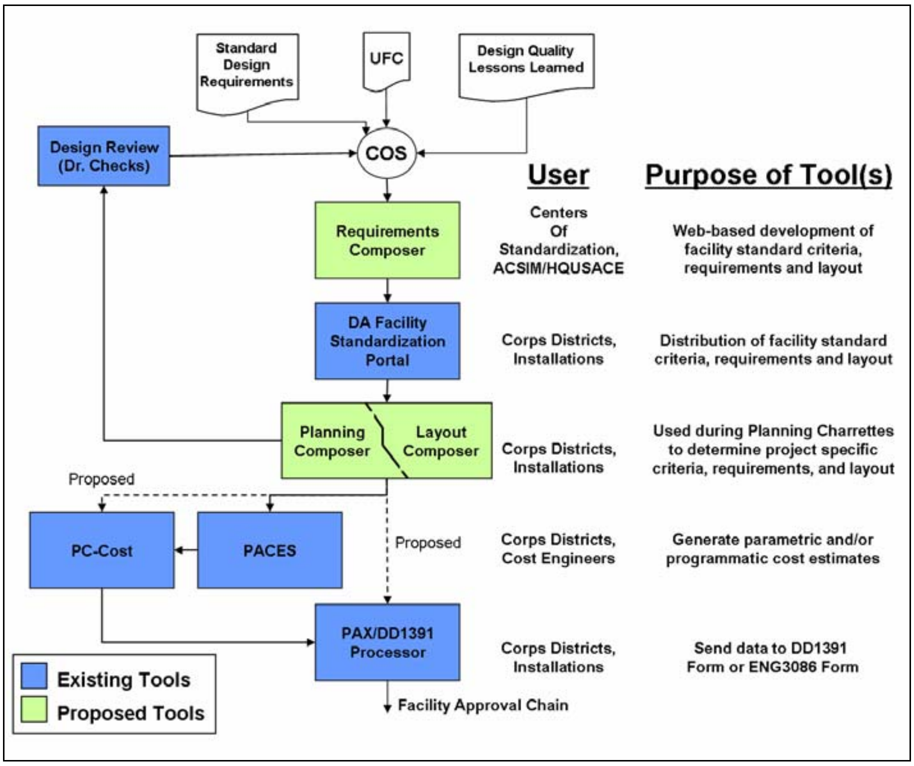

Figure 10: Proposed Process for Distribution of Army Standard Designs

Facility Composer was intended for more flexible standards and one-of-a-kind facilities. Since the Chapel is a full standard, this pilot will test Facility Composer in a different way. Instead of allowing a checklist of possible solutions for certain criteria, this test will hopefully demonstrate the system's ability to constrain planners from adopting different facility criteria and requirements.

8 Conclusion

The evolution of the IFC facility modeling standard has made it possible to capture criteria and requirements during planning and design, and to then reuse this data during the life cycle of the facility. ERDC-CERL's Facility

Composer supports the capture and tracking of facility criteria and requirements during planning charrettes so that the information in the object model can be used for downstream analyses such as cost, sustainability, and force protection. Facility Composer tools will ensure that standard criteria and requirements are the basis of all Army facility designs, and allow criteria updates to rapidly generate consistent project documentation, improving our credibility with congress.

Before the adoption of modeling Army standard criteria and requirements can become standard practice, industry and corporate buy-in on IFC exchange file formats, early design and programmatic modeling components, and the development of IFC Views for architectural programming needs to happen.

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